Environmental Health Perspectives
Vol. 32, pp. 131-141, 1979

Recent Application of Quantification II in Japanese Medical Research

by Takaichiro Suzuki* and Akio Kudo†

Hayashi's Quantification II is a method of multivariate discrimination analysis to manipulate attribute data as predictor variables. It is very useful in the medical research field for estimation, diagnosis, prognosis, evaluation of epidemiological factors, and other problems based on multiplicity of attribute data. In Japan, this method is so well known that most of the computer program packages include the Hayashi Quantification, but it seems to be yet unfamiliar with the method for researchers outside Japan.

In view of this situation, we introduced 19 selected articles of recent applications of the Quantification II in Japanese medical research. In reviewing these papers, special mention is made to clarify how the researchers were satisfied with findings provided by the method. At the same time, some recommendations are made about terminology and program packages. Also a brief discussion of the background of the quantification methods is given with special reference to the Behaviormetric Society of Japan.

Introduction

An epidemiological study is essential when in the association between a human disease and an etiological factor is of interest. It is ideal for handling etiology of infectious diseases. The situation is much more complicated in the developed countries where heart attack, cancer, stroke, and other chronic diseases are dominant. Diagnosis, the recognition of a disease, becomes an estimation problem and in many cases requires follow-up observations to confirm a prognosis. In other words, there is considerable informations involved, and usually no one datum is strong enough to explain the matter by itself. So the situation is always multivariate. Moreover many of them are attributes. Some of them are barely measured only by qualitative categories.

To manipulate such a situation, Hayashi proposed a set of statistical methods, namely, Hayashi's Quantification I, II, III, and IV. We would like to confine ourselves to the Quantification II in this paper, because it is expected to have the widest application.

It will not be unfair to say that the quantification methods introduced by Hayashi have not been made well available at the disposal of statisticians outside Japan. Perusal of the program of joint meetings of the American Statistical Association, the Biometric Society, ENAR and WNAR, Institute of Mathematical Statistics, in August 1978 gives us an impression that some in Social Statistics Section of ASA might be familiar with the methods, and there is enough convincing indication that his name is entirely ignored or unknown to those in biometrics.

In Japan, Hayashi's methods of quantification are so well known and their computer programs are so widespread that most of the program packages, which include factor analysis, principal component analysis, also have methods of quantification. Some biometricians may argue that factor analysis is merely a seemingly sophisticated method of expressing complex realities and its only justification is that the outcome of the analysis often coincides with prior knowledge, and speculation or indication remains as it was even after tedious analyses. They may argue further that it is not capable of offering any scientific evidence but merely rhetorics in terms of matrix and vectors. The same could be applied to the quantification methods. This is one of the reasons why many Japanese mathematically minded statisticians have shied away from the quantification methods.

It should not be ignored, however, that the quantification methods offer some knowledge about a set

*Section of Epidemiology, Department of Field Research, The Center for Adult Diseases, Osaka, Japan.
†Department of Mathematics, Faculty of Science, Kyushu University, Fukuoka, Japan.

of multivariate data, like a histogram does for univariate data and a dendrogram does in the case of cluster analysis for sets of multivariate data. One cannot ignore the fact that a great number of people in Japan are satisfied with findings provided by the quantification methods.

The second method of quantification, or Quantification II, corresponds to that used in classifying observations in two or more populations and seems to be least difficult to describe in English, yet no appreciable effort has been made to do so. It is impressive that of the 19 articles (*1-19*) reviewed in this paper only one (*16*) was published in English. It is hoped that the review in the following sections will serve to stimulate the interest of statisticians outside Japan on quantification methods.

Quantification II seems particularly suited for use in medical diagnosis, where available data are mostly qualitative and often an ordering among categories in an item is not previously known. In this connection Tanaka's contribution (*20*) is quite interesting, as it enables us to utilize previous information on ordering.

What is needed at present seems to be glossaries of English terminologies related to quantification. It is unfortunate to note that most of the papers reviewed contains statements either ambiguous or inadequate, leading to reader confusion or misunderstanding.

Quantification II is really a method of multivariate discrimination analysis expanded to manipulate attribute data as predictor variables. Someone attempting to apply that method would be interested in one of the following three issues: discrimination, prediction, and the evaluation of predictor variables.

A brief review will be given of 19 selected articles (*1-19*), all of which are concerned with recent applications of Quantification II in the Japanese medical research. This review will concentrate mainly upon the methodological problems, refraining from medical issues in each paper.

Discrimination

A differential diagnosis or the classification of a disease is the medical expression of a discrimination problem. Let us start from this original usage of the Quantification II.

The first three reports (*1-3*) deal with the diagnosis of a disease. The criterion variables in these studies is an alternative judgement, such as an early gastric cancer or benign diseases, Minamata Disease (chronic organic mercury poisoning) or not, gastric cancer or not. All of their predictor variables are attribute data measured only by nominal scale; endoscopic morphological findings, neurological symptoms, and gastrointestinal complaints respectively.

Hirokado (*1*) selected 32 cases of early gastric cancers (depressed type) and 44 cases with benign depressed lesions. All of those 76 cases had received gastrocamera examination, and were histologically proved. His purpose was to discriminate those two groups by using 22 gastrocamera findings. Under the assumption of linear regression equation, he maximized the multiple correlation coefficient, where he assigned a $+1$ score to a cancer case and a -1 score to a benign case. Solving the linear simultaneous equations, he obtained the optimal scores for the 22 gastrocamera findings as shown in Table 1.

According to his criteria, shown in Table 1, he succeeded to differentiate all 76 cases correctly. Then he applied that method to another 50 histologically proved cases, and obtained the correct diagnosis in 49 cases.

The result is very beautiful, but the readers would be a little confused as far as Quantification II is concerned. First, the author clearly referred to the Hayashi Quantification method, and stated that he would maximize the multiple correlation coefficient, as in the Quantification I, in spite of the fact that his external criterion was qualitative. Quantification I and II are equivalent if the external criterion is zero —one type which has not been documented in any of the literatures. Secondly, he initially calculated the scores only when the findings existed, and so a zero score would be implicitly assigned when it does not exist, but it does not imply that zero score should be assigned in case of unconfirmed nonexistence. The unconfirmed case is nothing but a case of a missing value, and he proposed to substitute an estimated population mean. This is an interesting proposal, subject to further assessments.

Hamada (*2*) explains the method just as a linear discriminant function, and there is no comment about the Hayashi Quantification. The method of describing the results, however, is completely similar to the method of Quantification II.

Hiraoka (*3*) applies Quantification II, the Quantification III, and the Bayes' Theorem. Then he evaluates the results by using the Lusted "Receiver Operating Characteristic Curve" (*21*). This illustration is quite convenient to us for the comparison of discrimination procedures.

In the next two reports (*4*) (*5*), authors manipulate two kinds of predictor variables mixed, one is an attribute, another is a measurement classified into several categories.

Kitazawa (*4*) assigns six stages of glaucoma into his criterion variable, and calls his method "categorical canonical discriminant analysis."

Table 1. Scores of gastrocamera findings for diagnosis of gastric cancer.[a]

Gastrocamera findings	Cancer confirmed	Cancer not confirmed
Gastric mucosa		
1. Atrophic gastritis	−0.184	−0.138
2. Hyperplastic gastritis	−0.085	−0.067
3. Hypertrophic gastritis	−0.351	−0.068
Ulcer shape		
4. Irregular	−0.151	−0.042
Ulcer margin		
5. Sharp demarcation	0.061	0.035
6. Erosion	−0.051	−0.010
7. Erythema	0.386	0.234
8. Edematous swelling	−0.155	−0.071
9. Smooth	−0.138	−0.036
Ulcer bottom		
10. Flat	−0.173	−0.078
Crater edge		
11. Sharp demarcation	0.753	0.327
12. Hemorrhage	0.251	0.010
Crater bottom		
13. Roughness	0.191	0.083
14. Hemorrhage	−0.034	−0.004
15. Dirty color	0.085	0.007
16. Island-like mucosal elevation	0.269	0.036
17. Spotted erythema	0.200	0.047
Property of coating		
18. Thin coating	0.157	0.157
Surrounding mucosa		
19. Nodular elevation	0.158	0.081
20. Interrupted fold	0.252	0.114
21. Clubbed fold	0.251	0.088
22. Tapering fold	0.074	0.011

[a]Discriminant criterion: cancer case $\geqq 0.144 >$ borderline case $\geqq 0.224 >$ benign case.

Okuda (5) refers to the Hayashi Quantification II, and applies it to each five sets of samples. Using the first set of samples, he tried to differentiate early gastric cancer (63 cases) from advanced gastric cancer (41 cases) based on four items of endoscopic findings. He obtained the optimal category scores, as shown in Table 2; 71% of cases could be differentiated correctly.

This paper contains three more analyses of similar materials. These are apparently calculated by different program packages, as the figures are in different formats and magnitude and one of them is given in Table 3.

In spite of all the confusion in nomenclature and program packages, the percentages of correct differentiation or classification are impressively high. Al-

Table 2. Scores of endoscopic findings to differentiate early gastric cancer from advanced gastric cancer (for IIc with converging fold type or IIc + III type).[a]

Item	Category	Category score
Size of IIc lesion	< 4 cm	0.28
	≧ 4 cm	−0.22
Characteristic findings of converging folds	None	−1.01
	Tapering only	0.92
	Interrupted	−0.03
	Clubbed or fused	−0.63
Size of III lesion	III nonexistent	0.11
	< 2 cm	−0.10
	≧ 2 cm	−0.65
Rigidity of IIc lesion	Not observed	0.52
	Observed	−0.49

[a]Discriminant criterion: advanced cancer $\leqq -0.4 <$ early cancer.

Table 3. Scores of endoscopic findings to differentiate mucosal cancer from advanced cancer (for III + IIc type).[a]

Item	Category	Category score
Size of IIc lesion	< 4 cm	2.53
	≧ 4 cm	1.69
Characteristic findings of converging folds	Tapering only	
	Not observed	0
	Observed	−3.47
	Interrupted	
	Not observed	0
	Observed	−2.87
	Clubbed or fused	
	Not observed	0
	Observed	−3.41
Size of III lesion	< 2 cm	0
	≧ 2 cm	0.72

[a]Discrimination criterion: mucosal cancer ≥ −0.09 > advanced cancer.

though these percentages are generally based on an internal sample, Hirokado's findings (*1*) based on an external sample or an additional independent sample, are encouraging. This is the reason why Quantification II enjoys warm acceptance in the Japanese medical community.

Kawagoe (*6*) presented a very unique application of Quantification II to the differential diagnosis of congenital heart diseases with shunt, because all of his predictor variables are measurements from the dye dilution curve. The usual procedure is to use linear discriminant function after making some transformations on variables. There is no statement why Quantification II is preferable to the linear discriminant function itself.

Prediction

Prediction is, in a sense, an inverse application of discrimination, and Quantification II is also useful in prediction. Prognosis is a medical expression of a special case of prediction. Its medical definition would be a forecast as to the probable results of an attack of disease. Six reports (*7-12*) will be introduced here in this respect.

Three reports (*7-9*) of these are the same type of study, dealing with the prognosis of heart attack. For example, Kato (*9*) collected data of so-called coronary risk factors from 83 cases of myocardial infarction before the onset, and the same kind of data from 767 control cases who have never had myocardial infarction. Using the Hayashi Quantification II, he figured out the category scores as shown in Table 4. According to his criterion, occurrence of heart attack in 87% of cases could be predictable.

Since Kobayashi (*7, 8*) and Kato (*9*) belong to the same research group, they must have used the same statistical procedure, in other words, the same computer program. Kato describes the method fairly in detail. In these studies, "the terminology normalization of category score" is used in a different sense. Usually the term, normalization, means to let the mean equal zero and the variance equal one, but Kato treated only the former condition. This might be the reason why they obtained quite large category scores in the several categories.

Also his report offers another problem of nomenclature as follows. Tanaka (*20*), indicated that the principle of the Quantification II is to maximize the correlation ratio or the between-groups variation relative to the total variation. Kato (*9*) uses the term, "correlation ratio," as the square root of the Tanaka's correlation ratio, and he calls the Tanaka's correlation ratio "discrimination efficiency." Again methodological and terminological uniformity would be needed.

In obstetrics, predicting a prolonged labor, Kubo (*10*) applies the Quantification II to the two sets of samples, one for primipara the other for multipara. Scores for multiparas are about ten times those for primiparas in each category. We wonder if any reasonable medical interpretation exists. It seems to us those for multipara have usual values according to our experience with the Quantification II. Also Kitazawa (*4*) presented much smaller category scores than Kubo's primipara. In this case, the numerator might have been divided by variance itself instead of the standard deviation.

Two papers by Komazawa (*11*) and (*12*) deal with the same study. One is a complete report of his work (*12*), but a set of category scores, however, is described in the other paper (*11*). He utilized data on 41,866 persons from a mass screening program for arteriosclerotic diseases to predict the onset of the diseases within one year later. He observed 53 cases of myocardial infarction, 44 cases of angina pectoris, 71 cases of cerebral infarction, and 31 cases of cerebral hemorrhage after one year observation. He drew a sample of size 215 as control matched by sex and age to the 199 disease cases. After preliminary analysis by Quantification II on 199 pairs and 41,667 persons he performed two kinds of analyses; first, he worked out a prediction of onset or not, secondly, predicting which disease of four was likely, both on the samples of size 199 and 215.

The optimal category scores he obtained are shown in Table 5. In his second analysis, cases were classified in three-dimensional space, then he found that the first axis discriminated cerebrovascular diseases and cardiovascular diseases, the second axis divided cerebral infarction from cerebral hemorrhage, both in high accuracy, but, the third axis

Table 4. Prediction of myocardial infarction.

Group of item		Item (j)	Category (k)	Normalized scores $x_{jk}' = x_{jk} - \bar{x}_j$
I	1	Sex	Male	1.3817
			Female	−3.8380
	2	Age	≤ 49	−3.5349
			50-59	−2.2901
			60-69	4.2104
			≥ 70	14.0180
II	3	Blood pressure		
		Grouping of pressure[b]	Normotensive	1.2745
			Borderline	−2.3339
			Hypertensive	−2.2603
	4	Systolic pressure	≤ 150 mm Hg	0.0562
			> 150 mm Hg	−0.1670
	5	Diastolic pressure	≤ 90 mm Hg	−1.4041
			> 90 mm Hg	5.3389
	6	Serum cholesterol	≤ 175 mg/dl	−2.2815
			176-225 mg/dl	−1.5875
			226-279 mg/dl	2.6356
			≥280 mg/dl	4.3912
III	7	Diabetes mellitus	−	−0.7299
			+	2.0152
	8	Type of AP[c]	−	−5.7885
			AP of effort	48.1415
			AP at rest	56.4667
			Effort + rest	30.5359
			Variant	48.6753
IV	9	EKG findings		
		Heart rate	60 ~ 90	0.1679
			> 90	3.8899
			< 60	−3.0801
	10	Abnormality of ST-T wave	Normal	−1.9196
			Flat T	−2.0998
			Negative T	15.5682
			ST depression	−2.3099
			ST depression flat T	14.4424
			ST depression negative T	7.7073
			ST elevation	27.3385
	11	Disturbance of stimulus formation	Normal	−0.6766
			Supraventricular premature beat	22.6745
			Ventricular premature beat	1.4910
			AF + ventricular premature beat[d]	4.9568
	12	Disturbance of stimulus conduction	Normal	−0.3924
			Abnormal	9.4186

[a]Predictive criterion: onset ≧ 4.37 > no onset.
[b]Normotensive = systolic pressure ≦ 150 mm Hg and diastolic pressure ≦ 90 mm Hg except both equal simultaneously; hypertensive : systolic pressure ≧ 200 mm Hg or diastolic pressure ≧ 110 mm Hg; borderline : between normotensive and hypertensive.
[c]AP = angina pectoris.
[d]AF = atrial fibrillation.

divided myocardial infarction from angina pectoris with rather low accuracy.

Komazawa is a young colleague of Hayashi. This study is therefore, an excellent example of the application of Quantification II. In fact, he treated quite systematically not only the Quantification II itself but also relevant problems including Quantification III.

Evaluation of Predictor Variables

The evaluation of predictor variables would be the most appealing application of the Quantification II for epidemiologists if we could use it unconditionally. The difficulties in interpreting outcome of analysis caused by complex set of correlations among variables exists also in quantification

Table 5. Scores for discriminating arteriosclerotic diseases.

Item	Category	Category score (onset or not)	Category score (which disease)		
			1st axis	2nd axis	3rd axis
Sex	Male	−0.012	0.372	0.099	−0.248
	Female	0.053	−1.527	−0.406	1.020
Serum total cholesterol, mg/dl	≦ 139	0.234	1.200	0.420	1.421
	140-179	0.112	−0.110	0.266	0.698
	180-219	0.039	−0.070	0.082	0.112
	220-259	0.163	0.169	−0.486	−0.445
	≧ 260	−0.879	0.086	−0.205	−1.320
Fundus examination (scheie)	S-0	0.227	−0.075	0.096	−0.121
	S-I	−0.138	0.236	−0.430	0.291
	S-II	−0.862	−0.175	0.495	0.052
	S-III·IV	−2.304	0.480	−0.852	0.260
EKG (Minnesota)	Normal	−0.030	0.239	0.127	0.222
	High-R	0.685	−0.127	−1.477	−0.494
	ST-T change	−0.071	−0.567	0.079	−0.103
	ST-T change + high-R	−1.037	−0.358	−0.671	−0.229
	Other abnormal findings	0.280	−0.102	0.616	−0.529
Systolic blood pressure, mm Hg	< 119	1.149	−0.243	0.961	−1.029
	120-139	0.341	−0.658	−0.001	−0.787
	140-159	−0.403	0.045	0.520	0.214
	160-179	−0.273	−0.004	−0.538	0.461
	≧ 180	−0.529	0.813	−0.591	0.339
Aortic pulse rate (m/sec)	≦ 7.4	0.436	−0.326	−0.985	−0.247
Velocity of aortic pulse	7.5 ~ 8.4	−0.052	0.272	−0.452	−0.111
	8.5 ~ 9.4	−0.398	−0.005	0.257	0.163
	9.5 ~ 10.4	0.244	−0.493	1.089	0.068
	≧ 10.5	0.168	0.449	0.326	0.077
Correlation ratio		0.172	0.243	0.176	0.131
Rate of correct discrimination		0.702	0.668	0.814	0.628

methods like any other multivariate statistical methods. Under this effect, we might obtain unreasonable category scores, against our common knowledge.

In seven reports (*13-19*) which are reviewed here, it is suggested that the partial correlation coefficients or the range of the category score in an item be used. It is, however, not clearly stated anywhere in what situation each one is better and in what respects.

The purpose and method of two reports (*13, 14*), are quite similar, both applying sequential analysis and Quantification II. Reference is made to two English articles (*22, 23*) and some expository papers in the Japanese medical journals and these are only to sequential analysis, showing the adequate reference in quantification is nonexistent in the Japanese medical community. They investigated what kind of symptom was really controllable by the specified drug. They evaluate it by using partial correlation coefficients between the external criterion, either drug or placebo, and the estimated criterion variable by Quantification II.

Watanabe (*14*) treated 31 cases of Meniere's disease by Betahistine and placebo alternatively (so-called cross-over design), and investigated the change of symptoms and examination data. Then he applied the Hayashi Quantification II, and obtained the results shown in Table 6. He concluded the drug was effective in improving vestibular dysfunction, nausea, deafness, and stiff shoulder. His conclusion is based on a kind of intuitive judgement about the relative magnitudes in partial correlations. Some readers may feel uneasy about the fact that for the value of partial correlation no physically recognizable model or phenomenon exists. It may well be much easier to consider the percentage of correct differentiation or classification.

The categorical scores are so adjusted that the mean of the scores in each item is zero, but not normalized, and this is called standardized score.

There are three reports (*15-17*) in regard to the healing of gastric ulcer. One report (*16*) is practically an English edition of a previous one (15), and only one medical application is written in English. But, as far as Quantification II is concerned, its description is not so systematic as Komazawa's (*12*). Nakajima (*16*) tried to assess factors affecting healing of gastric ulcer, based on 263 cases of healing (within 90 days) and 156 cases of delayed healing. He used the Hayashi Quantification II, but he did not present the

Table 6. Effects of Betahistine for Meniere's disease.[a]

Item	Category	Standardized score	Range	Partial correlation coefficient
Age	30-39	−1.6229		
	40-49	−11.2663		
	50-59	31.0429	82.7871	0.163
	60-69	−51.7442		
Sex	Male	−16.8927	41.0250	0.109
	Female	24.1324		
Light-headedness	Improved	−18.2800		
	Unchanged	24.5818	71.7899	0.153
	Aggravated	−47.2081		
Episodic vertigo	Improved	−10.7348		
	Unchanged	−7.7507	62.4527	0.112
	Aggravated	51.7179		
Tinnitus	Improved	71.0547		
	Unchanged	−24.6226	92.6773	0.229
	Aggravated	−6.6853		
Deafness	Improved	15.9816		
	Unchanged	−11.9960	221.9645	0.246
	Aggravated	209.9686		
Headache	Improved	32.6174		
	Unchanged	−1.1938	90.3208	0.146
	Aggravated	−57.7034		
Stiff shoulder	Improved	27.3944		
	Unchanged	11.6104	130.2564	0.223
	Aggravated	−102.8621		
Nausea	Improved	103.7425		
	Unchanged	−26.1721	129.9146	0.258
	Aggravated	−7.8834		
Vestibular dysfunction	Improved	114.2707		
	Unchanged	−23.5917	198.9569	0.320
	Aggravated	−84.6863		
Nystagmus	Improved	−9.4443		
	Unchanged	20.8220	85.2659	0.140
	Aggravated	−64.4439		
Impairment of hearing	Improved	80.9715		
	Unchanged	−2.8846	105.1848	0.095
	Aggravated	102.3002		

[a]Correlation ratio = 0.572.

table of the category scores in his paper. Table 7 is constructed from his data as far as possible. He found the site of the ulcer to be the most important factor influencing the healing of the ulcer. He did not normalize the category scores, and evaluated the factors using its range. Some different terminologies are used as indicated in Table 7.

Ida (*17*) deals with the same kind of study. He also evaluated factors using the range of the category scores. But, in his case, the category scores had been normalized.

The final two reports reviewed here (*18, 19*) may be quite interesting subjects, because of the typical direct approach to the evaluation of epidemiological factors using the Quantification II. Yanai (*18*) tried to detect risk factors for gastric cancer. For this purpose he sampled 729 gastric cancer cases and 671 controls from the data of a large scale retrospective case-control study, where 4193 persons were interviewed about food habits and occupational environment. Using the Hayashi Quantification II, Yanai obtained the optimum category scores for every specified age group. Based on these scores, he concluded that there are enough indications that somatic tiredness, low income, eating cups of rice 7 per day, eating hot meals, eating foods too quickly, and overindulgence in alcohol are the factors associated with high risk groups tending to develop gastric cancer.

Yoshimoto (*19*) investigated risk factors for gastric ulcer utilizing 200 cases and 200 controls in each age group from the above large-scale study. The category scores obtained by his analysis are shown in Table 8. In this case, scores are normalized so that the comparisons between age groups were possible. The findings include, among others, that the range of scores in occupation hazard increases with age whereas the range in income decreases, and that the

Table 7. Factors influencing delayed healing of gastric ulcer.

Item	Category	Category score	Range[a]
Sex	Male		
	Female		0.920
Age	≤ 30		
	31-40		
	41-50	1.000	
	51-60		
	≥ 61	0.000	1.000
Ulcer history	Negative		
	Definite		0.774
Therapeutic environment	In-patient		
	Out-patient		0.398
Site 1	Upper body	0.863	
(Along the longitudinal	Middle body	0.779	
axis of the stomach)	Lower body	0.589	
	Angle	0.000	
	Antrum		2.141
Site 2	Lesser curvature	0.349	
(Along the horizontal	Greater curvature	0.000	
axis of the stomach)	Anterior wall	1.155	
	Posterior wall	0.010	1.145[b]
Shape	Round or oval		
	Irregular		
	Linear		0.501
Depth	Shallow (5 mm)		
	Moderate (5-10 mm)		
	Deep (10 mm)		0.209
Size	Small (5 mm)	0.433	
	Middle (5-15 mm)	1.081	
	Large (15 mm)	0.000	1.081
Coexisting gastritis	No gastritis		
	Atrophic gastritis		
	Other gastritis		0.413
Complication	Negative		
	Definite or suspected		0.776

Accuracy discriminating these two groups 67.2%

[a]The range of category scores in an item is assumed to be called "weight of factor" in Fig. 3 of Nakajima's text.
[b]This value might well be 1.155 if the category scores are correct.

range in cigarette smoking stays large throughout all age groups. A possible interpretation will be that occupational hazard increases with age, and importance of income decreases with it.

In this regard we feel that Table 8 offers the most convincing presentation as to the efficacy of Quantification II. The authors feel any program package should provide the normalized scores as one of the standard routine programs.

As we have seen, Quantification II was confused with Hayashi's first method in one work (*1*), and it was called the linear discriminant function in another (*2*), and categorical canonical/discriminant analysis in a third (*4*). Another possible name would be categorical linear discriminant function. Quantification II or Hayashi's Quantification II is most concise and least confusing, and we hope this terminology will be acceptable in the English-speaking world.

Background of Quantification Methods

Most of the studies related to the quantification methods seem to have been presented through the Behaviormetric Society of Japan, whose president is Dr. Chikio Hayashi and whose office is now Institute of Statistical Mathematics, 4-6-7, Minami-Azabu, Minato-ku, Tokyo, 106. The Society has two publications: Behaviormetrika publishes articles in European languages, and The Japanese Journal of Behaviormetrics is for publication in Japanese. The very first issue of the Japanese journal, published March 1974, contains seven special articles. All these articles are concerned with the future of the society.

In a special preface to the first issue (*24*), Dr. Hayashi called for scientific efforts of the members,

Table 8. Scores of risk factors for gastric ulcer.

Item	Category	Age 30-39		Age 40-49		Age 50-59		Age ≥ 60	
		Score	Range	Score	Range	Score	Range	Score	Range
Occupational hazard	Dust and heat	0.062		0.128		0.119		0.007	
	Somatic tiredness	0.057		0.080		0.093		0.127	
	Mental stress	−0.082	0.19	−0.191	0.48	−0.245	0.55	−0.154	0.75
	Not particular	−0.123		−0.348		0.305		−0.623	
Income per month	≤ 50,000 yen	−0.172		0.032		−0.019		−0.033	
	50,000-60,000	0.303		0.199		0.081		0.024	
	60,000-80,000	0.176		0.126		0.112		0.051	
	80,000-100,000	−0.182	0.66	−0.004	0.33	−0.122	0.24	0.016	0.25
	100,000-120,000	−0.359		−0.210		−0.042		−0.187	
	120,000-150,000	−0.147		−0.110		−0.123		0.064	
	≥ 150,000	−0.330		−0.181		−0.021		−0.018	
Working hours per day	< 8 hr	0.195		0.106		0.090		0.140	
	≧ 8 hr	−0.097		−0.048		−0.011		−0.074	
	Night	0.292	0.39	0.003	0.15	−0.377	0.62	−0.094	0.41
	Irregular	−0.016		0.059		0.241		0.313	
Amount of rice eaten per day	No rice (bread)	−0.057		−0.041		0.072		0.114	
	< 6.5 cups per day	−0.017	0.15	−0.021	0.10	−0.040	0.11	−0.074	0.19
	≧ 7 cups per day	0.090		0.059		0.034		0.032	
Eating speed	Slow	−0.127		−0.093		−0.071		−0.000	
	Moderate	0.016	0.19	−0.033	0.15	0.040	0.11	0.067	0.10
	Quick	0.060		0.057		0.015		−0.029	
Hotness of foods	Cold	0.002		−0.099		0.005		0.084	
	Moderate	0.079	0.17	0.020	0.10	0.012	0.02	0.035	0.12
	Hot	−0.090		0.004		−0.011		−0.037	
Coffee drinking	No coffee	−0.020		0.043		0.009		−0.062	
	Occasionally	−0.044	0.12	0.004	0.10	−0.061	0.11	0.135	0.20
	Every day	0.076		0.061		0.042		0.083	
Milk drinking	No milk	−0.063		−0.065		−0.028		−0.097	
	Occasionally	0.028	0.12	0.040	0.11	0.027	0.06	0.047	0.18
	Every day	0.061		0.040		0.006		0.087	
Eating pickles	No pickles	−0.054		−0.047		0.139		0.025	
	Moderate	−0.018	0.07	−0.017	0.06	−0.157	0.30	−0.078	0.11
	Much	0.018		0.016		0.006		0.035	
Alcohol drinking	No alcohol	0.060		0.020		0.012		0.055	
	Occasionally	0.018		0.003		−0.062		−0.190	
	Every day (beer)	−0.215		−0.082		0.000		0.074	
	Sake 180 ml/day	−0.182	0.30	−0.060	0.12	−0.049	0.49	−0.196	0.38
	180-360 ml/day	0.047		0.025		−0.023		0.181	
	360-540 ml/day	0.083		−0.010		0.031		0.068	
	> 540 ml/day	−0.101		0.036		0.427		0.084	
Cigarette smoking	Nonsmoker	−0.185		−0.416		−0.289		−0.277	
(smoking index)	≤ 100	−0.150		−0.300		−0.184		0.061	
(no. of cigarettes	101 ~ 200	0.087		−0.220		−0.116		0.020	
per year)	201 ~ 400	0.078		0.001		−0.026		0.072	
	401 ~ 600	0.265	0.45	0.050	0.87	0.041	0.43	0.101	0.49
	601 ~ 800	0.049		0.033		0.085		−0.128	
	801 ~ 1000	0.154		0.097		−0.008		0.212	
	≧ 1001	0.000		0.458		0.140		−0.093	

and referred to some pioneering works in the Japanese history of science. He recalled that when he was young the exact sampling theory based on normality assumption and the inference theory constituted the main stream of statistics, which made him doubt if they are too narrow and/or vacuous. His recollection needs some comments here. After the second World War, the impact of statistical inference and decision theory just imported at that time was so great that a strange Japanese vocabulary was introduced: "Inference Statistics" as contrasted to "Descriptive Statistics." The emphasis was sometimes so emotional that "Inference Statistics" is regarded as science, and "Descriptive Statistics" is not.

Professor G. Iwata (25) of Ecometrics in Keio

University considered problems in behaviormetrics from the standpoint of econometrics, and, referring to Kuhn (*26*) concluded that although it will be in the remote future, there is conceivable a single unified science of human behaviors including jurical, political, economic, social, psychological, medical and other sciences. The references includes his works on applications of principal component and factor analysis.

Professor H. Ikeda (*27*) of Psychometrics and Educational Statistics in St. Paul University refers to the report of the Behavioral and Social Science Survey Committee (*28*). This was said to have been established in 1966, and included a psychophysician, Dr. D. A. Hamburg, and a statistician, Dr. W. H. Kruskal.

Professor M. Yamamoto (*29*) of Public Health in Teikyo University Medical School confessed that he is convinced of the usefulness of the quantification methods, particularly Quantification IV, in research of an interdisciplinary nature.

He disagreed with Hayashi's statement that the aim of the Society lies in methodologies. His arguments are based on the assertion that any set of methodologies cannot constitute a science. Behaviormetrics might well be, according to him, along the line of behavioral sciences started about 1920, and he proposes another possibility of putting the behaviormetrics in the line of "Science of Man" which is said to have been proposed by R. Linton in 1945. Following an article in philosophy (*30*), he developed his arguments. Behavioral science is now on the second stage, where various multivariate technics, such as factor analysis, analysis of variance, correlation analysis, Hayashi's quantification methods etc., are introduced. It will gradually go into a third stage, where various mathematical theories, such as cybernetics, information theory, and game theory will flourish. He has been trying to work out (nonmonetary) indexes for social development and/or social welfare (*31*). He reviewed a large number of works: his paper refers to 84 Japanese articles and 23 English articles, both including his papers, and we cite his paper in an English periodical journal (*32*).

As reviewed above, some Japanese are ambitiously striving to establish a new scientific discipline, with a gigantic scheme and an expansive philosophy. Another aspect of this Society is that it attracts a number of medical scientists interested in mathematical sciences, and has organized a number of sessions in its annual and occasional meetings. The terminology "mathematical" above is used in much larger context than it is used in the statement of the purpose of the Biometric Society. Indeed Professor H. Abe, a member of editorial board of Computer and Biomedical Research, and his colleagues are contributing a paper (*33*). It co-sponsored an International Conference on Cybernetics and Society, Nov. 3-7, 1978. Tokyo & Kyoto, and a number of members including medical scientists presented papers. What will emerge out of the activities of the Behaviormetric Society is to be seen, but whatever it may be it is certain that the terminology "biostatistics" is and will be of different flavor in the U.S. and in Japan.

The mathematical structure of Hayashi 's method is widely known, and medical application of his second method is regarded as a minor subject in Japan, but reference sources in journals easily accessible by medical reserach workers are missing. The publications of research achievements are not very easy. Komazawa's article (*34*) is perhaps the only expository paper in English. One of the authors, as an organizer of the conference, wishes that this article along with that of Tanaka (*20*) will initiate dialogues in the community of biostatisticians in Japan and the United States, namely criticisms, assessments, and further developments.

REFERENCES

1. Hirokado, K. Computer analysis of gastrocamera signs for diagnosis of early gastric cancer. Igaku-Kenkyu 37(3): 54 (1967).
2. Hamada, R., and Igata, A. Diagnosis of Minamata Disease. Suri-Kagaku 161: 30 (1976).
3. Hiraoka, T., Hashimoto, T., Soh, K., Umeda, K., Oshima, A., and Shimmura, S. The limit of possibility to detect gastric cancer cases by the use of a questionnaire. Gan-no-Rinsho 23(14): 1321 (1977).
4. Kitazawa, Y. Problems on primary open-angle glaucoma. Acta Soc. Opthal. Japon., 79: 159 (1975).
5. Okuda, S., Imanishi, K. Mimura, S., Konishi, M., and Oshima, A. Diagnosis for the depth of infiltration in early gastric cancer of depressed type, with reference to an application of mutivariate analysis. I-to-Cho 12: 1175 (1977).
6. Kawagoe, S., Goto, Y., Nagasawa, K., Kimura, E., and Hayashi, C. Differential diagnosis of congenital heart disease with shunt by dye dilution curve using the theory of quantification. Japan. J. Med. Electronics Biol. Eng., 15 (supplement): 274 (1977).
7. Kobayashi, M., Hashimoto, T., Shiohara, Y., Igarashi, H., Saito, I., Suzuki, Y., Kato, K., Fujimaki, T., Ishii, Y., Niitani, H., and Onoda, T. A study on short-term prognosis of acute myocardial infarction by discrimination analysis. Japan *Circulation J. 40: 502 (1976).*
8. Kobayashi, M., Kato, K., Ito, Y., Shiohara, Y., Igarashi, H., Saito, I., Fujimaki, T., Hashimoto, T., and Niitani, H. Estimation of prognosis of myocardial infarction by discrimination analysis. Saishin-Igaku, 33: 160 (1978).
9. Kato, K. Studies on clinical prediction of myocardial infarction: quantifications of coronary risk factors. Japan. Circulation J., 40 : 1041, 1055 (1976).
10. Kubo, T. Prediction of prolonged labor by means of quantification theory. Saishin-Igaku, 33, 162 (1978).

11. Komazawa, T., Hasegawa, M., and Yoshimura, S. The classification in the diseases of circulatory system by the quantification method. Saishin-Igaku, 33, 190 (1978).
12. Komazawa, T. Prediction of prognosis in arteriosclerotic diseases by the quantification method. Japan. J. Public Health, 25, 105 (1978).
13. Itoh, H., Okamoto, M., Miura, S., Kabeshima, Y., Shigeta, M., Mochizuki, N., Yaki, G., and Asaka, H. A double-blind, controlled trial on the value of Spiroperidol (a butyrophenone derivative) in schizophrenia — application of sequential analysis and discrimination analysis — Seishin-Igaku (Clinical Psychiatry), 9 (10) : 65 (1967).
14. Watanabe, T., Fukami, J., Yoshimoto, H., Ueda, Y., Suzuki, J., Okamoto, T., Takeuchi, M., and Onoda, T. A clinical trial of Betahistine in Meniere's Disease — double-blind test and multivariate discrimination analysis. Ji-Bi-Inko-Ka (Otolaryngology), 39 (11) : 93 (1967).
15. Osaka Inter-Hospital Research Group for Gastrointestinal Diseases. A report of the follow-up study of gastric ulcer in Osaka. Sogo-Rinsho (Clinic All-round), 23: 1850 (1974).
16. Nakajima, T. Studies on factors affecting healing of gastric ulcer. Am. J. Gastroenterol. 66 : 150 (1976).
17. Ida, K., Kawai, K., Nakajima, M., Miyaoka, T., Kohli, Y., Hashimoto, Y., Takeda, S., Toriie, S., and Takebayashi, M. Studies on the healing process of gastric ulcer — statistical examination of influential factors on healing and prediction of healing time. Japan. J. Gastroenterol. 72 (3) : 12 (1975).
18. Yanai, H., Yoshimoto, Y., Takagi, H., Toyokawa, H., Maeda, K., and Kurita, H. A statistical analysis of detecting risk factors for stomach cancer patients. Japan. J. Public Health, 24 (9) : 547 (1977).
19. Yoshimoto, Y., Takagi, H., Maeda, K., Yanai, H., and Kurita, H. A statistical analysis of risk factors for gastric ulcer. Japan. J. Public Health, 25 (2) : 64 (1978).
20. Tanaka, Y. Review of the methods of quantification. Environ. Health Perspect. 32: 111 (1979).
21. Lusted, L. B. Introduction to Medical Decision Making. C. C. Thomas, Springfield, Ill. 1968.
22. Bross, L. Sequential medical plans. Biometrics 8:88 (1952).
23. Armitage, P. Sequential Medical Trials. Blackwell Oxford, 1960.
24. Hayashi, C. Preface to the first issue of the journal. Japan. J. Behaviormetrics, 1(1) : 1 (1974).
25. Iwata, G. Problems of behaviormetrics from the standpoint of econometrics. Japan. J. of Behaviormetrics, 1(1) : 15 (1974).
26. Kuhn, T. S. The Structure of Scientific Revolutions. Univ. Chicago Press, Chicago, 1962.
27. Ikeda, H. Behaviormetrics as behavioral and social science. Japan. J. Behaviormetrics, 1(1) : 20 (1974).
28. Behavioral and Social Science Survey Committee. The Behavioral and Social Sciences: Outlook and Needs. Prentice-Hall, Englewood Cliffs, N.I. 1970.
29. Yamamoto, M. Problems of behaviormetrics from the standpoint of philosophy of science and health sciences. Japan. J. of Behaviormetrics, 1(1) : 30 (1974).
30. Yoshimura, T. Requirements of philosophy of man in the Twentieth Century. In: Iwa-Nami Ko-Za Tetsu-Gaku Vol. R. Mutai and K. Umemoto, Eds., Iwanami Shoten, Tokyo. 1968.
31. Baster, N., and Scott, W. Levels of living and economic growth: a comparative study of six countries 1950-1965. Report on an institute study. United Nations Research Institute for Social Development, Geneva, 1969.
32. Yamamoto, M. The development of social and health sciences in Japan. Social Sci. Med. 3: 639 (1970).
33. Ioue, M., Takasugi, S., Furukawa, T., and Abe, H. Optimal control of medical treatment. Japan. J. Behaviormetrics 1(1) : 55 (1974).
34. Komazawa, T. A statistical method for quantification of categorical data and its application to medical science. In: Decision Making and Medical Care. Can Information Science Help? F. T. Dombal, and F. Gremy, Eds., North Holland, Amsterdam, 1976.